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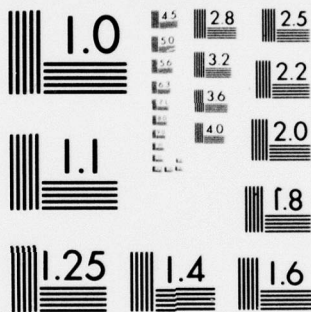
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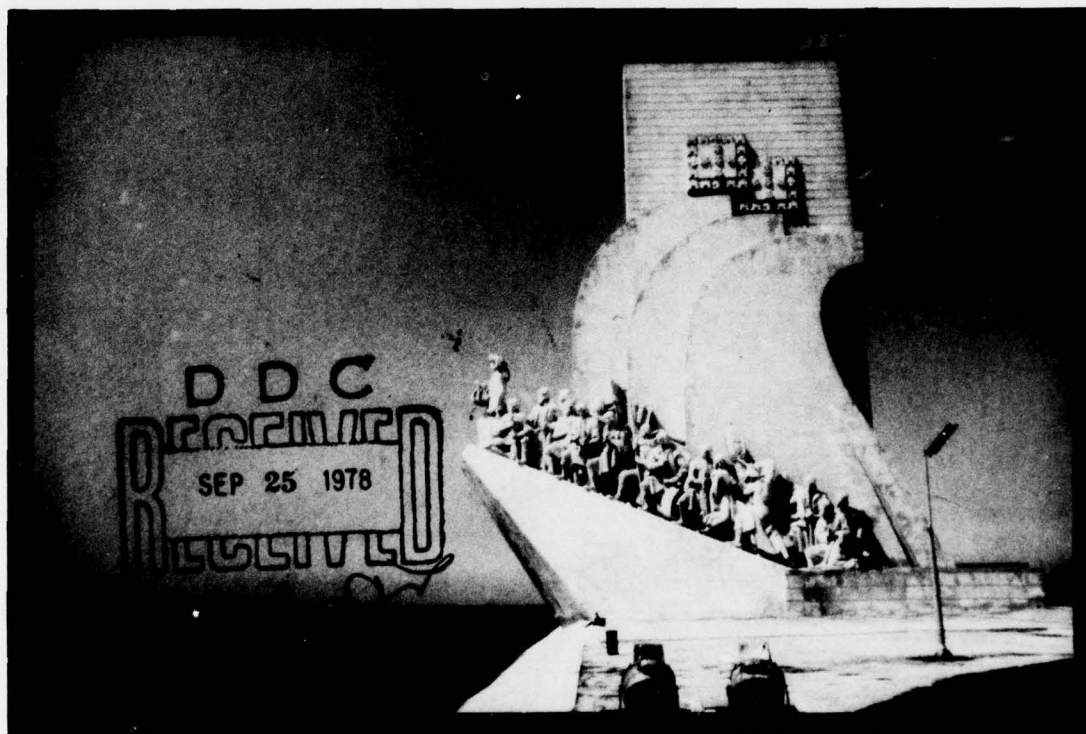
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HIGHLIGHTS



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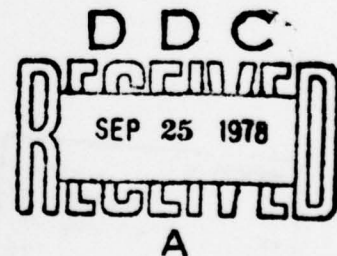
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THE MISSION OF AGARD

The mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Exchanging of scientific and technical information;
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;
- Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

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Foreword

In our last issue of AGARD HIGHLIGHTS - 78/1 - of March 1978 - I touched on an important subject of discussion of our National Delegates Board during its Annual Meeting in Copenhagen last Fall; that is, cooperative research and development activities with the smaller nations of the Alliance. I am happy to report that our scientific and technical Panels have responded positively to this call by organizing meetings and conferences of several Panel Officers with Portuguese scientists and engineers during the course of our 1978 Annual Meeting in Lisbon this September. In helping enhance the technical potential of its smaller member nations, the North Atlantic Alliance will, as a whole, gain in its collective strength.

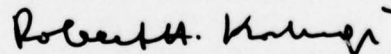
With reference to current areas of interest in aerospace science and technology covered by AGARD Panels and its Aerospace Applications Studies Committee, we have now firmed a set of Terms of Reference and accompanying Topics Lists which will be published shortly in the form of an AGARD document available through national distribution centers listed on the back cover of this publication.

Those who attended our National Delegates Board Meeting in the Spring of this year will no doubt recall the fascinating talk on various facets of aerospace medicine given so masterfully by Air Commodore Cooke, Deputy Chairman of the Aerospace Medical Panel. At the time we had planned to publish the written version in the present issue of the Highlights. Unfortunately, this has not proved possible; however, we shall try to make arrangements to publish it later on.

~~In the present issue we follow~~ past practice of presenting a feature article on the areas of interest of our scientific and technical Panels with an exposé on Electromagnetic Wave Propagation by the Chairman of this Panel.

On the personal side, shortly after its spring Meeting, our National Delegates Board suffered the tragic loss of one of its new and active members, Helmut Langfelder of the Federal Republic of Germany, who was killed in a helicopter crash. During his short term as National Delegate, the youthful Chairman of Messerschmitt-Bölkow-Blohm made an indelible mark on AGARD. The whole AGARD community mourns Helmut Langfelder's passing and extends its deepest sympathy to his family and to the Federal Republic of Germany. He is remembered in this issue.

I recall that the HIGHLIGHTS is designed to give news of the AGARD community. I hope that you will enjoy reading this issue and that it will encourage one and all to submit contributions of articles for future issues.



Robert H. Korkegi
Director, AGARD

All members of AGARD, whether National Delegates, Panel Members of AGARD Staff, are cordially invited to submit articles likely to be of interest to other AGARD members for the next issue of AGARD HIGHLIGHTS which will appear in the Spring of 1979. Articles should be addressed to:

Scientific Publications Executive
AGARD-NATO
7, rue Ancelle
92200 Neuilly sur Seine
France

or, from US and Canada only:

AGARD-NATO
APO New York 09777

Front cover:

LISBON, PORTUGAL

Memorial to the Discoveries –

Rising above the river like the prow of a symbolic caravel this monument is embellished by a magnificent group of statues. They stand on the two ramps which flank the memorial and represent the important personalities linked with the Discoveries. At the point of the prow rises the figure of Prince Henry the Navigator, followed by seamen, cartographers, artists, cosmographers, missionaries, and others.

Above the sails of the caravel is a wall bearing on either side the Arms of Portugal at the time of the Discoveries, while at the back of the monument, above the doorway, there rises a sword with the cross of Aviz on the hilt – symbol of military strength and Faith in God.

(NATO Photo)

PARIS JOUR...



Photographs taken during the AGARD 44th NATIONAL DELEGATES BOARD MEETING held in the Conference Room of the Western European Union building in Paris in March 1978.

Explaining a point (top picture) is present AGARD Director, Dr Robert H. Korkegi, with Dr Frank L. Wattendorf (US), Honorary Vice-Chairman of the National Delegates Board and, on the right, Mr Frank R. Thurston, the Board's Chairman.



...et PARIS SOIR



Hosts for the occasion at the Reception given by the French Authorities for AGARD National Delegates and the guests were l'Ing. Général Bosch and Mme Bosch, shown here on the right of the picture. Being welcomed are American National Delegate Dr Alan M. Lovelace and his wife.



On the previous evening, AGARD also had the pleasure of offering hospitality to its guests. Dr and Mrs Korkegi are here seen greeting Dipl.-Ing. Heinz Max, Federal Republic of Germany, present Chairman of AGARD's Flight Mechanics Panel.

NATIONAL DELEGATE THREESOME

L'Ing. Général P. Contensou, of France, in conversation with British colleagues Mr J. Alvey and Dr E.W.E. Rogers, who recently joined the Board and is currently Deputy Director (A) of the Royal Aircraft Establishment at Farnborough.



AVIONICS PANEL CHAIRMAN

Ir H.A.T. Timmers (on the right), from the Dutch National Aerospace Laboratory, seen here with Dr Lovelace, US National Delegate, and Colonel (ret'd) John M. Coulter (US), the NASA Coordinator for AGARD. Having just presided over the Panel Chairmen Meeting Mr Timmers no doubt had earned that drink!

FRENCH AIR FORCE Colonel J.R. Lepine, a Member of the Review Board of AGARD Project 2000, being greeted by a smiling Ing. Général Contensou at the reception at the Cercle Militaire. In the background are French National Delegate l'Ing. Général R. Boscher and Mme Boscher.

VISITOR FROM NATO HEADQUARTERS
on the occasion of the AGARD Reception was Mr K. Müller, the Director of the Armaments and Defence Research Directorate in the Defence Support Division, here seen with the AGARD Director and his lady.

TWO OLD HANDS TOGETHER.
Long-experienced in the affairs of French aerospace and of AGARD are Professor L. Malavard, Member of the National Delegates Board and l'Ing. Général A. Vialatte, a former French National Delegate.



Electromagnetic Wave Propagation in Aerospace Research and Development

by

H.J. Albrecht

Chairman, Electromagnetic Wave Propagation Panel

THE SCOPE OF THE SUBJECT

Historically, the use of the "air" surrounding our Earth as a medium for carrying mechanical devices, such as aeroplanes, dates back to around the last decade of the nineteenth century, roughly the same time that this very same medium was coming to be used as a carrier for wireless waves on their way from one point to another. Both developments have proved to be of significant importance to the evolution of our modern world, and for the benefit of mankind.

Both fields have experienced enormous progress. Initial leaps and glides have led to interplanetary space-travel; first wireless contacts from one room to another have evolved into interplanetary communications. Moreover, the interdependence of these two great technical developments has become more and more pronounced. Today, modern aerospace systems would be unthinkable without equally modern means of telecommunications and navigation, and, vice versa, these modern methods are assisted by satellites in space.

Perhaps this sine-qua-non condition is somewhat in favour of telecommunications and navigation in their utilization of our planet's atmosphere, since such services can also be provided quite satisfactorily without "assistants" in space, if the influences of the medium are properly recognized and systems are adapted appropriately.

It is this problem of medium behaviour which is a major concern in the design of up-to-date systems. In other words, knowledge of the effects of the medium upon the propagation of electromagnetic waves represents the key to the solution of modern telecommunication and navigation problems. In addition, propagation characteristics are very useful indicators of medium composition and its changes, as well as of dynamic behaviour, such as turbulence. Furthermore, the study of adjacent media of propagation interest is important;

examples are the behaviour of solid material in general and the Earth's surface in particular, all with regard to their effects upon electromagnetic waves.

Within AGARD, the Electromagnetic Wave Propagation Panel deals with all subjects relating to the propagation aspects of electromagnetic waves in the context of aerospace research and development; special attention is paid to scientific analysis and evaluation as well as the application of their results in communications, navigation, guidance, and surveillance. Major fields of activity are as follows:—

- structures and dynamics of the propagation media in the Earth environment
- propagation in the atmosphere, in ionosphere and troposphere, including disturbances, scattering processes, absorption, prediction, and forecasting
- electromagnetic propagation in the entire spectrum, from low frequencies to optical wavelengths, including noise effects, aspects of optical propagation, antenna fields, patterns, and polarization
- propagation aspects of systems, i.e., propagation effects on total system design
- ground characteristics, including interactions and effects of terrain, vegetation, and structures.

PROPAGATION MEDIA

As has already been indicated, a propagation medium may be defined as any solid, gaseous, or liquid material in which an electromagnetic wave propagates. Depending upon the state of the art, knowledge of medium characteristics is steadily increasing with some configurations of waves of certain frequency ranges in certain media, or may have reached some saturation level prior to new advances in measurement technology and methods of analysis. Nevertheless, the media of

For more than a decade, Dr Hans J. Albrecht has been an AGARD panel member, first in the Guidance and Control Panel, and, since 1969, in the Electromagnetic Wave Propagation Panel. He also served as director of an AGARD Aerospace Application Study on modern communication systems (AAS No.10). Among other tasks within NATO, he was chairman of an R&D programme for tactical satellite communications (1967–1975). Dr Albrecht received a doctor's degree in engineering science from the Technical University (Technische Hochschule) of Aachen and is a Fellow of the Institution of Radio and Electronics Engineers, Australia. In 1977 he was elected President of the FRG committee of the URSI (International Union of Radio Science).



primary interest are generally those in the atmosphere of our planet, mainly the ionosphere and troposphere and adjacent regions.

Figure 1 illustrates the atmospheric environment and its effect on all frequencies within the spectrum 10 kHz to 100 GHz. Altitude above ground and frequency are drawn to logarithmic scales. On the left-hand side are shown generally-adopted designations for regions of the atmosphere. Within the troposphere, a distinction has been made for typical altitude ranges of clouds in lower, medium and upper heights. The difference in average altitude of the tropopause between equator and polar regions is also shown. The change in electron density between D, E, F₁ and F₂ layer regions is responsible for different reflection characteristics. The logarithmic altitude scale permits us to find, within the illustration, the altitude for geostationary satellites as well as that of the moon. Looking at the atmospheric behaviour within the entire frequency spectrum we have first of all the ionospheric reflection up to frequencies of about 30 MHz with some partial transparency in the lower frequency range, depending upon the relationship of operating frequency to gyro-frequency and upon the direction of propagation with respect to the magnetic field lines. The range of ionospheric scatter propagation and meteor backscatter is shown up to 100 MHz. The so-called "radio-window" for communications with spacecraft and satellites is shown to commence at about 100 MHz, its upper limit being governed by high attenuation on frequencies of the order of 10 GHz and higher. It should be emphasized that all popular tropospheric propagation links also use frequencies within this radio-window. In the upper portion with respect to frequency, the effects of precipitation may represent a significant source of difficulties while the absorption line of O₂ around 60 GHz renders impossible ordinary links through such a medium.

Another parameter of interest is the noise characteristics within the entire frequency range. Again, a "window" of low noise temperature should be taken into account when selecting frequencies for certain links. Atmospheric noise, for instance, increases with decreasing frequency, while cosmic noise decreases.

The Earth's surface is an important propagation medium which may become effective in several ways. These refer to action upon antenna characteristics in the so-called near-field of the antenna, to attenuation for ground-wave propagation along the surface, to the effects of vegetation and of ground parameters on the reflection properties with respect to wave polarization, intensity, and phase, and, with subsurface propagation, to the attenuation experienced by a wave travelling through a layer. The two characteristic parameters, ground conductivity and dielectric constant, are functions of humidity and temperature, and of frequency; they may be considered variable with appropriately detrimental effects upon wave propagation. The geographical distribution of ground characteristics is of importance when considering world-wide communication or navigation applications and the behaviour of the ground in reflections. Connected with the Earth surface as a propagation medium is water in its various configurations, with salinity and other parameters being responsible for changes in the electromagnetic characteristics.

As we have said, any medium in which an electromagnetic wave propagates is a propagation medium. Thus, any solid, liquid or gaseous material may be functioning as such a medium. On the other hand, the use of propagation within electric or electronic components is no more of interest for electromagnetic wave propagation research and development, once such fundamental problems have been solved and technological realization has commenced.

AREAS OF APPLICATION

Fundamentally, application areas of electromagnetic wave propagation may be subdivided into communications, navigation, and other links supporting aerospace systems. Using the two aforementioned link types as examples, typical characteristics of propagation paths may be identified. They are depicted in Figure 2 and are indicated in terms of frequency ranges, features such as predominant medium parameter, bandwidths possible, and distances, followed by types of terminal, and limitations by propagation. For these purposes of comparison, three categories of terminal have been utilized to differentiate between the wide scale of possible combinations. Fixed terminals of constant location are designated as stationary ones, whereas mobile terminals are those in operation while in motion. The intermediate type, comprising terminals which are transportable but not in operation while in motion, has been called "transportable". The limitation characteristics due to propagation behaviour have been listed in the figure; they are described in very general terms, more details are given in the subsequent section.

On the left-hand side of the illustration, *Line-of-Sight* paths and those based on *Diffraction* around obstacles are shown. Links in these categories may use any frequency, but mainly those above 30 MHz have been implemented as such. With line-of-sight links in addition to the feature of a geometric limitation by line-of-sight conditions, the type of terrain below the path and the environment may cause severe multipath effects, which may lead to appropriate bandwidth limitations. On the other hand, abnormal tropospheric conditions, such as inversion layers in the troposphere, may give rise to reflections and to multipath occurrence of temporary as well as variable nature. Nevertheless, proper attention to problems due to propagation characteristics permits the use of these paths for links connecting stationary, transportable, and mobile terminals.

The use of the diffraction mechanism is theoretically possible and represents an imperfect but nevertheless existing form of propagation paths in the fringe zones of line-of-sight conditions. Signal fluctuations are common; their dependence upon propagation media is similar to that mentioned under the line-of-sight conditions.

The next column deals with *Reflections at Ionospheric Layers*. These form in different regions of our planet's atmosphere, on the basis of ionization caused by various processes. In most cases, a dependence on solar radiation and solar activity has been verified. The action of the ionosphere upon propagation is very complex. Although largest distances on the Earth surface may be covered by such links, and even with a minimum of radiated electromagnetic energy, the proper use of special features of this propagation mechanism requires expertise and continuous research.

For large distances the wave is reflected once or several times at an appropriate height within the ionosphere, and perhaps, though not necessarily but possibly, at one or more intermediate points on the Earth surface. With reflection heights varying between 100 and 400 km (see Figure 1) surface distances amount from zero to a maximum of the order of 4000 km if the horizontal layer structure is parallel to the ground; far larger distances may be covered if the layer is inclined with respect to the ground beneath it, with the excitation of a chordal path inside and along the layer, or by a sequence of single reflections. The complexity of propagation via ionospheric reflections leads to different path components with the consequence of a reduction in the bandwidth of such links.

The maximum propagation frequency depends upon the state of ionization which is governed by the time required for a neutralization or recombination of ions and electrons and by the strength of the ionizing radiation. Whereas the former parameter is a function of atmospheric density or, largely, of the height above the Earth's surface, the latter is determined by solar radiation and thus by a variety of components, as time of the day, season, and solar activity. A measure for the last-mentioned variable is the number of sunspots.

Although a large number of variables in ionospheric propagation has been investigated successfully during the last fifty years and although results are useful for reasonably reliable average predictions, a continuing augmentation of relevant knowledge, for instance on irregular and abnormal characteristics, allows an increasing implementation of modern technologies.

Turning to *Scatter Paths* as another typical application area, it may be remembered that appropriate research was initiated about three decades ago in order to increase the overall reliability of terrestrial communication. Features are illustrated in the next column of Figure 2. With this type of propagation, a volume in the atmosphere, a so-called scatter volume, is illuminated by a transmitter and the energy scattered towards the receiving terminal is being used for the communication link. Obviously, energy requirements of such systems are much larger than those of line-of-sight links; however, the overall reliability of the scatter links may under certain conditions be better. Distances larger than those of line-of-sight links, and moderate bandwidth requirements are representative applications. Two types of scatter propagation have become known: ionospheric scatter using volumes at the altitudes of the D-layer and tropospheric scatter using scatter volumes below the tropopause. Stratospheric scatter links have also been tested. Any scatter mechanism usually leads to a limitation in the bandwidth which may be transmitted.

Irregularities or variations of electron density in the height region of the D-layer, between 70 and 90 km, are one basis of a ionospheric scatter mechanism. These variations can be considered to be due to turbulent mixing; they provide regular but weak scattering. In addition, the passage of meteors through the atmosphere causes a shortlived existence of ionized trails which may lead to intermittent reflections, useful for burst communications. Furthermore, diffuse reflections may be due to patches of a layer in the E-region of the ionosphere, the so-called sporadic E-layer, or due to irregularities in the higher regions of the ionosphere, approximately in the upper F₂-layer. The typical frequency range for

ionospheric scatter propagation commences above the highest yet regularly reflected frequency in the short-wave range, around 30 MHz, and is generally limited to frequencies of the order of 100 MHz. On account of path geometry, maximum possible distances amount to the order of 2000 km.

With tropospheric scatter propagation, the scatter mechanism may be based on turbulence, using scatter elements formed by random fluctuations of the dielectric constant, or on diffuse and partial reflections from layer-like structures in the troposphere. The mechanism is similar to the ionospheric one but higher frequencies are usually employed; the typical range extends from about 1 to 15 GHz. Depending again upon geometric limitations given by the altitude range of the scatter volume, distances of 100 to 600 km may be covered.

Communication or navigation links using artificial *Satellites in Space* represent a relatively young application area. The transparency of the atmosphere in certain frequency regions, in so-called "radio-windows" (see Figure 1) enables such space links to be established. The right-hand column in Figure 2 illustrates some of their features. They are also applicable to guidance and surveillance use.

In principle, satellite uses resemble line-of-sight links with a relay or reference terminal in space. Earlier experiments in space communications used passive satellites, such as "Echo", which reflected energy arriving from an earth terminal back towards the Earth, thus enabling reception by another Earth terminal. With the advancement in aerospace technology, and thus in direct connection with it, active repeaters in space took their place. Initially, these satellites displayed only elliptical, non-stationary orbits, "Telstar" being an early example. As time went on, the precision attainable in launching satellites increased, and today, highly accurate positioning of satellites in geostationary or any other suitable orbits belongs to the state of the art. Geostationary or quasi-geostationary orbits are normally circular at low inclination angles with regard to the equator. They are useful for most requirements in geographical areas up to a certain high latitude. For special purposes, elliptical orbits are employed.

As far as path characteristics of space links are concerned, they can obviously be considered similar to line-of-sight conditions if frequencies in the ranges of transparencies are utilized. Depending upon frequency and geographical location of surface terminals, severe limitations due to ionospheric irregularities may occur in the various applications indicated. Figure 3 shows the geographical regions most affected. Relevant research activities are progressing in many countries and are of particular practical value in an attempt of optimizing the otherwise most advanced methods of communication and navigation provided by artificial earth satellites.

NATURAL AND TECHNOLOGICAL LIMITATIONS

As has already been indicated, limitations in using propagation paths for any purpose vary in different frequency ranges on account of conditions of environment, noise, and changes in parameters which affect the path, either by reflection, scatter, or absorption.

In Figure 4 an attempt has been made to illustrate the more important propagation path characteristics as a function of frequency, effective atmospheric altitude

ranges, and typical distances. These three parameters are represented by mutually perpendicular axes using logarithmic scales throughout. This graphical synopsis is now to be commented upon in somewhat more detail.

Commencing with very low frequencies (VLF) shown at the top of the figure, a world-wide coverage is possible by means of waveguide-like propagation in the belt formed by the Earth's surface and the lowest ionospheric layer, the D-layer, whose relatively low electron density is adequate for a reflection of these frequencies. Obviously, changes in the characteristics of both boundary zones influence the quality of such paths and may represent inherent limitations to their use. Assuming a path between two points to follow a great-circle on the Earth's surface, electrical characteristics of this surface region, as well as the diurnally and seasonally variable state of D-layer ionization, affect the amplitude of a signal and its phase, which may, for instance, cause deviations in measurements of times of arrival and thus influence essential navigation data.

With regard to somewhat higher frequencies and, e.g., long-distance paths in this range, which is usually referred to as "high-frequency" or "short-waves", the state of ionization in the here relevant layers — F_2 and perhaps F_1 , and E — is an essential source of variability, again in addition to earth-surface characteristics in possible reflection areas. On the other hand, the latter feature is of no effect with chordal paths which, by definition, do not touch the surface; as has been mentioned in the previous section of this paper, such conditions prevail for certain distance ranges with regularly existing inclined horizontal structures in ionospheric layers, within dawn zones and towards the path ends. The following, rather large portion of the spectrum from about 30 MHz to frequencies of the order of about 100 GHz accommodates a number of applications for propagation paths. Figure 4 illustrates the information given in previous sections.

Irregularities in the ionosphere may limit the usefulness of satellites in certain geographic regions and up to about 10 GHz; on higher frequencies, rain and other precipitation may severely affect communication and other paths between Earth and space. In any portions of the spectrum abnormal tropospheric conditions may cause changes in path geometry, such as inversion layers or other types of unusual gradients of the refractive index as a function of altitude. Additional sources of path unreliability towards the higher frequencies of the total spectrum may be represented by attenuation due to fog, and signal fluctuations or scintillations due to turbulence characteristics.

In the interest of clarity, Figure 4 does not include scatter links using irregularities in the ionosphere. Those in the tropospheric regions are indicated with typical distance and useful frequency ranges. The reliability of such scatter links depends on the turbulence structure in the tropospheric scatter volume, or on conditions prevailing for another scatter mechanism, such as partial reflections at layer-like structures. Disturbances in the weather can thus cause significant changes in limitations with respect to required power and obtainable bandwidth. Some time ago, studies aiming at better reliability under average conditions resulted in the use of so-called diversity paths, i.e., a simultaneous transmission of the signal by means of several path components differing slightly in spatial antenna position, frequency,

or portion of the scatter volume provided that both, frequency of operation and antenna beamwidth, permit an adequate distinction between path components.

The dependence of this propagation mechanism upon weather conditions and the inherent sensitivity to relevant disturbances represent a direct connection to other aerospace fields and, in particular, their measurement techniques. An appropriate cooperation within the AGARD community can be considered to be of great mutual benefit.

The bottom portion of Figure 4 shows line-of-sight links which are representative of typical use in most parts of the entire spectrum, up to optical frequencies above frequencies of the order of 10 THz (Tera-Hertz). Features and functions have been described before. Depending upon the frequencies utilized, electrical characteristics of the ground, abnormal gradients of refractive index, attenuation due to precipitation and fog may all influence the reliability and may thus represent limitations.

With regard to technological limitations on frequencies below about 10 GHz, the above comments and those in the previous sections on power requirements may presently still govern the employment of small equipment intended for mobile or portable applications. With increasing frequency, this type of limitation may more and more concern the present feasibility of at all implementing links of one or the other configuration, depending upon power levels and operational stability achievable. Activities in research and development aim at a steady improvement.

R & D TREND IN PROPAGATION MEDIA

Objectives of research and development in electromagnetic wave propagation comprise an optimization of links for communication and other purposes by identifying, predicting, and where possible, mastering difficulties indicated in the previous section. Work has recently commenced on a perhaps very powerful, future tool: the artificial modification of propagation media to achieve maximum efficiency and optimization. Up to a certain degree such remedies concern all portions of the electromagnetic wave spectrum and all fields of applications. Activities of the Electromagnetic Wave Propagation Panel during the last few years, and particularly in 1976, have led to indicative results.

In *Ionospheric Radio Wave Propagation*, the impact of satellite technology about ten years ago caused a change with regard to the application of ionospheric research results to problems connected with this new type of path requiring an optimum atmospheric transparency. Already in the late sixties activities of the then Electromagnetic Wave Propagation Committee concerned ionospheric irregularities as one significant source of possible limitations. Research work continues with the objective of optimizing communication and other links using this path configuration.

Additional activities in the field of ionospheric propagation refer to the extension of the useful spectrum by means of artificially modifying the medium such that the maximum usable frequency for high-frequency long-distance propagation (so-called MUF) is increased and the lowest usable frequency ("LUF") is lowered. A promising method of extending the maximum usable frequency is represented by "ionospheric heating", or

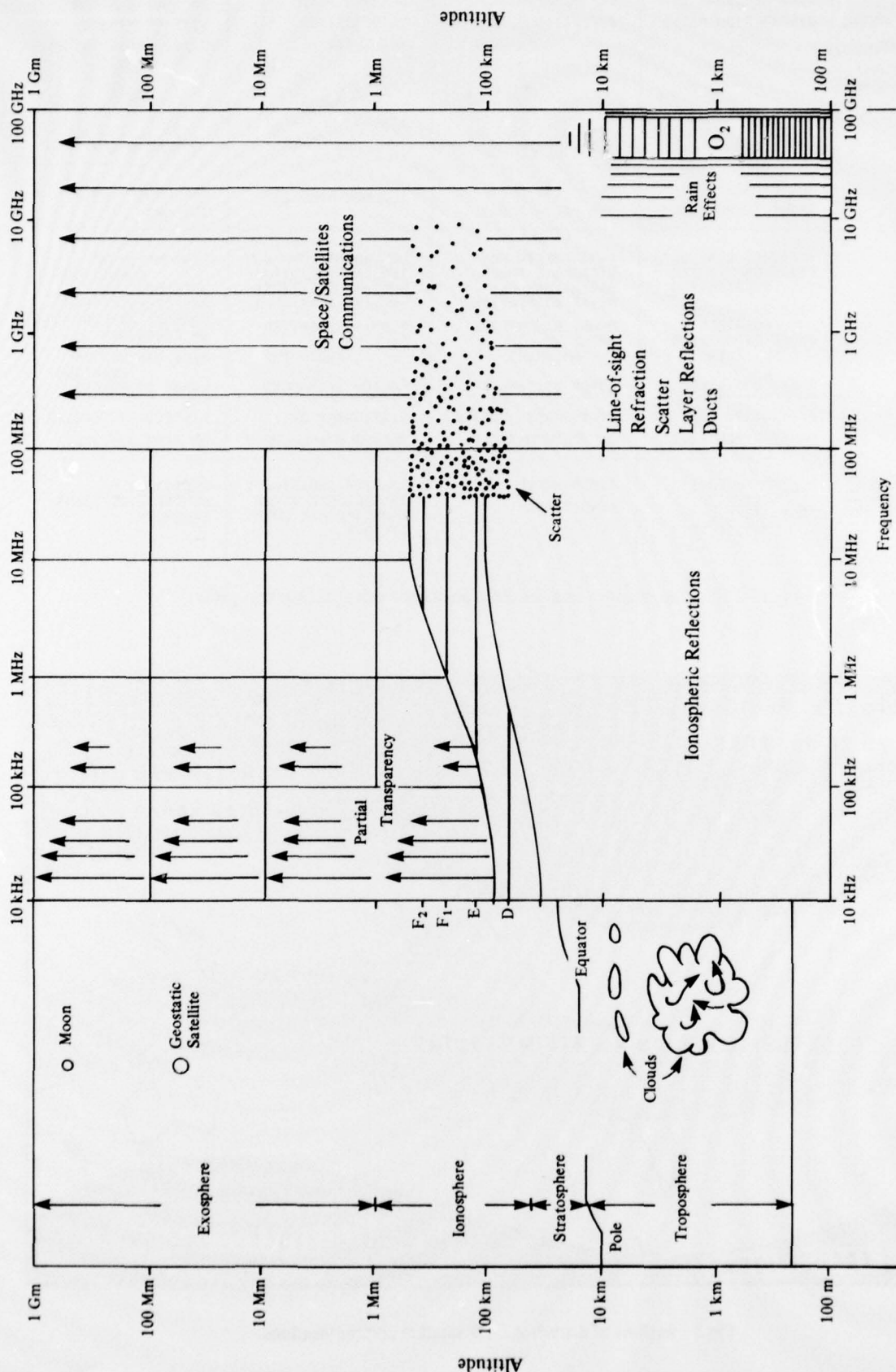


Fig.1 EM-wave propagation 10 kHz — 100 GHz

(H.J. Albrecht 1968/76)

TYPICAL APPLICATION AREAS OF ELECTROMAGNETIC WAVE PROPAGATION PATHS

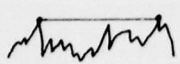

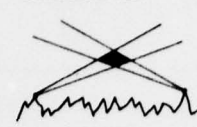
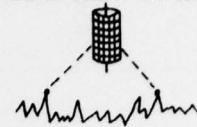
TYPE OF LINK (COMMUNICATION, NAVIGATION, GUIDANCE AND SURVEILLANCE)	LINE-OF-SIGHT & DIFFRACTION PATHS	VLF-MF-HF-PATHS- REFLECTIONS AT IONOSPHERE	SCATTER PATHS TROPOSCATTER IONOSCATTER	SATELLITE LINKS LINE-OF-SIGHT RADIO RELAY IN SPACE
				
FREQUENCY RANGES	ALL RANGES ABOVE 30 MHZ	HF 3 - 30 MHZ AND BELOW 3 MHZ	100 MHZ - 15 GHZ	ALL RANGES ABOVE 100 MHZ
FEATURES	STRICTLY LINE-OF- SIGHT OR DIFFRACTION WIDE BANDWIDTHS POSSIBLE UNDER FAVOURABLE CONDITIONS SHORT DISTANCES	IONOSPHERIC CON- DITIONS & THEIR VARIATIONS RE- QUIRE ADAPTATION SMALL BANDWIDTHS SMALL NO. OF CHANNELS LARGE DISTANCES	DEPENDENCE ON SCAT- TER CAPABILITY OF MEDIUM VARIATIONS REQUIRE ADAPTATION WITH IONOSCATTER ONLY SMALL BANDWIDTHS MEDIUM DISTANCES	LINE-OF-SIGHT CONDITIONS DEPENDENT ON ATMOSPHERIC TRANS- PARENCY AS FUNCTION OF FREQUENCY WIDE BANDWIDTHS POSSIBLE LARGE DISTANCES
TYPE OF TERMINAL	STATIONARY, MOBILE OR TRANSPORTABLE	STATIONARY, MOBILE OR TRANSPORTABLE	STATIONARY OR TRANSPORTABLE ONLY	STATIONARY, MOBILE OR TRANSPORTABLE
LIMITATIONS BY PROPAGATION	MULTIPATH ENVI- RONMENT TROPOSPHERIC CONDITIONS	IONOSPHERIC CONDITIONS	SCATTER CAPABILITY OF MEDIUM & OTHER TROPOSPHERIC CON- DITIONS	CONSTANCY OF ATMOSPHERIC TRANS- PARENCY

Fig.2 Typical application areas of electromagnetic wave propagation paths

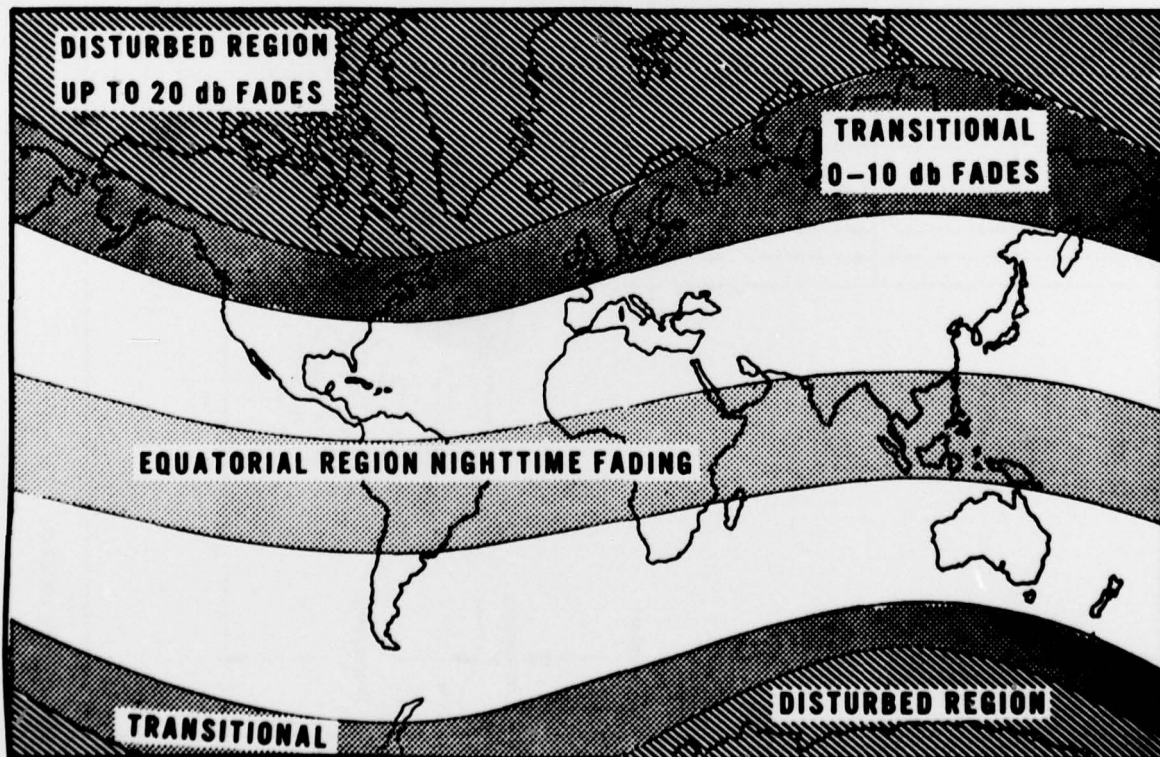


Fig.3 Regions of disturbed UHF satellite communications

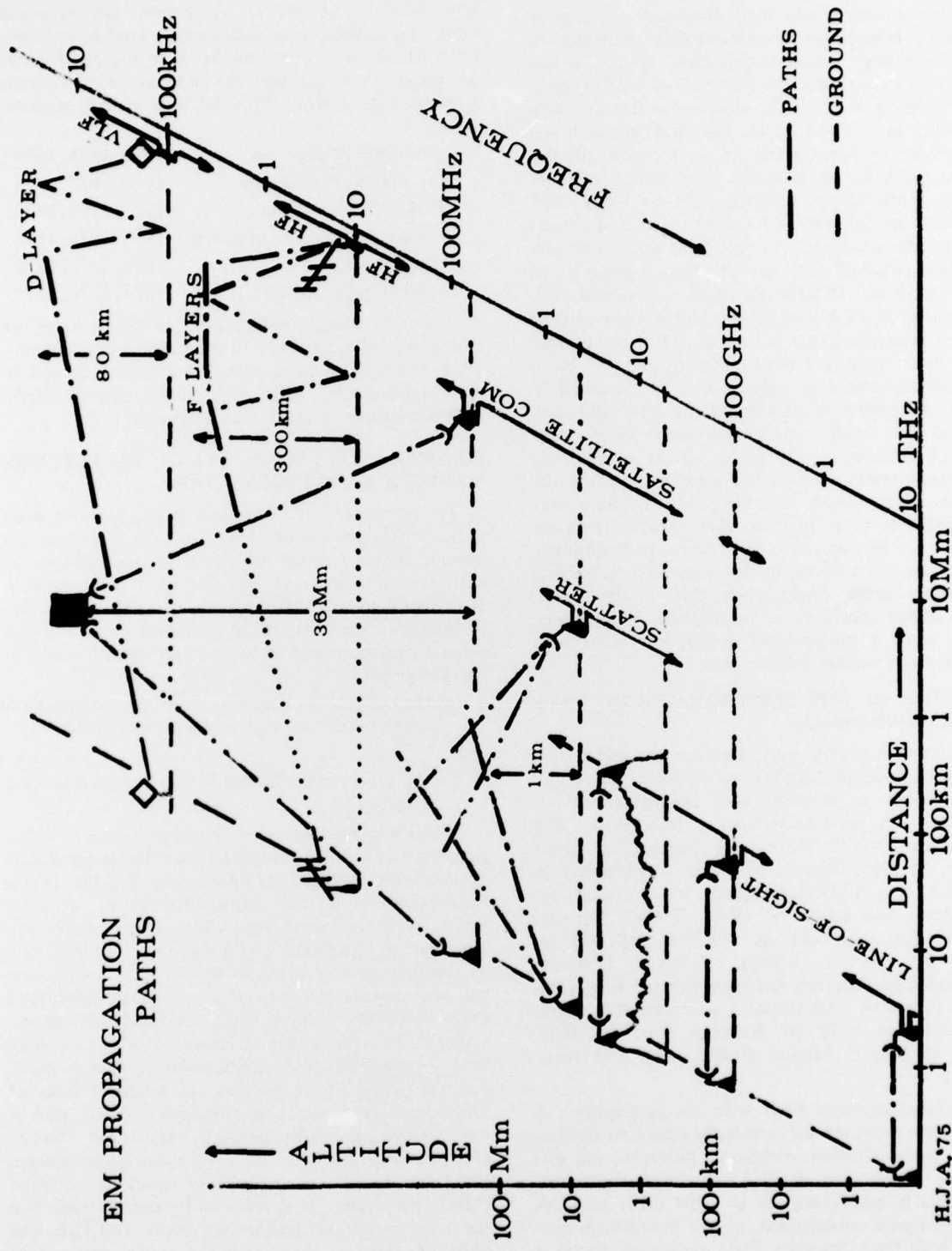


Fig.4 EM propagation paths

the use of extremely high radio wave energy to heat a certain portion in the ionosphere which in turn assists in forming a satisfactory propagation mechanism for frequencies above the natural maximum usable one. The reduction of the lowest usable frequency may perhaps be achieved by the release of chemical substances in certain ionospheric volume.

In *Tropospheric Radio Wave Propagation*, a steadily progressing technological development has enabled the use of increasingly higher frequencies; this process can be expected to continue with the result of reliable equipment becoming available in ranges of millimetre, sub-millimetre, and optical waves. As far as research and development in propagation media is concerned, this progress leads to an increasing importance of work directed at identifying, analyzing, and predicting areas, occurrence, and intensity of natural limitations discussed in the previous section. An enormous amount of data has been collected on relevant links operating on frequencies below 10 GHz, such that only special questions remain to be solved. An example is the variable effect of inversion layers in the vicinity of line-of-sight paths; such work is just commencing and will be of particular importance in connection with the establishment of topographical data banks for automatic computerized link design. As another example measurements of attenuation and phase effects of rain and other precipitation are now being undertaken in many countries of the world; an appropriate evaluation may be expected to result in reasonable statistical data for link design. Similar to its application in ionospheric propagation, the artificial modification of tropospheric propagation media should, some time in the future, yield a higher reliability in tropospheric propagation. In this case, a predominant connection exists with experiments in weather modification.

ACTIVITIES OF THE ELECTROMAGNETIC WAVE PROPAGATION PANEL

In more than twenty years, the Electromagnetic Wave Propagation Panel of AGARD and its predecessors have now attended to research and development fields indicated in the previous sections of this review. The panel originated as the Ionospheric Research Committee in 1956. In 1965, the field of activity was extended to the entire area of electromagnetic wave propagation. Panel status was granted in 1970. F.Lied (Norway) was the first chairman in 1957/58, followed by P.Newman (United States), E.Vassy (France), M.Anastassiades (Greece), B.Burgess (United Kingdom), I.Paghis (Canada); past chairmen since elevation to full panel status in 1970 are K.Davies (United States), O.Holt (Norway), I.Ranzi (Italy), and P.M.Halley (France).

The Panel concerns itself with the propagation of electromagnetic waves and, especially with their application to communication, navigation, guidance, and surveillance. In addition, detailed knowledge of propagation media is made available to assist other activities in the aerospace environment, as, for instance, in connection with fluid dynamics, flight mechanics, guidance and control, etc. Main objectives of the Panel ensure a close connection to basic research; on the other hand, the interface contact between research and application is also regarded as one of the essential tasks in order to achieve optimum efficiency in the Panel's service to the aerospace community.

For more than two decades, the Panel has now succeeded in organizing a large number of typical activities such as symposia, specialists' meetings, lecture series, working groups, consultant missions, and other advisory work. It has become a managerial practice to permit a complete coverage of interim results and advancement of knowledge in each of the detailed fields in intervals of approximately two years. Some years ago, technical areas were defined as an intermediate level of organizational structure. As an indication of the constructive repetition in area coverage, the more recent and relevant meetings appear below with the dates of their sponsorship:

— Ionospheric Propagation:	1975, 1978, 1979
— Tropospheric Propagation:	1976, 1977, 1978
— LF/MF/HF Propagation:	1977, 1978, 1979
— Propagation Aspects of Systems:	1975, 1976, 1978
— Optical Propagation:	1975, 1977, 1978
— Ground Characteristics:	1974, 1976, 1979

Activities under consideration for future years are closely related to the trend in research and development. They extend from predominantly research-oriented to more applicational fields, with certain emphasis upon interface areas with other AGARD-panels.

POSSIBLE LONG-TERM TREND IN ELECTROMAGNETIC WAVE PROPAGATION

The assessment of a long-term trend, or the forecast of future research and development in the field under discussion, meets with the difficulties of, and displays the same causes of error as, any long-term trend analysis. With regard to some trend examples, a previous section of this paper mentions appropriate assumptions. A more general treatment may be based on tentative forecasts in two categories:

- (a) the effect of progress made in technological development in adjacent and supporting areas, and
- (b) the progress in research in Electromagnetic Wave Propagation.

The first-mentioned category includes areas in which progress may be derived directly from the technological advancement predicted for forthcoming decades. In this connection the present development in an advancing feasibility of the employment frequencies higher than 100 GHz, in combination with the steady accumulation of research data referring to those higher frequencies, will probably lead to their use for conventional types of links for communication, navigation, guidance and surveillance, such as terrestrial line-of-sight links, satellite links for transmission between terrestrial and, perhaps, airborne terminals, as well as for kinds of links of increasing importance as the space-age advances, such as inter-satellite and interplanetary links. The steadily accumulating amount of data will most likely concern the behaviour of the propagation medium on those higher frequencies. It should also be kept in mind that the employment of frequencies above 100 GHz will ultimately lead to the use of the entire spectrum of electromagnetic waves with the coverage of the interval presently neglected, for instance between about 100 GHz and the optical frequency ranges, as orders of magnitude. To some degree, this advancing use of frequencies above 100 GHz will most likely be caused by the frequency requirements which will undoubtedly

increase as the needs in communication and other fields will be more and more predominant with the general technological development to be anticipated for forthcoming decades.

Considering the actual technological effectiveness of the general development to be expected, the stability of equipment for those higher frequencies just mentioned will probably reach the criteria presently achievable for microwaves up to 100 GHz. On the other hand, data on the behaviour of the propagation media will be more reliable because of an increase in their statistical significance. Keeping in mind that the atmospheric propagation media as, for instance, the troposphere, will affect signal attenuation and related characteristics, the development in forecasting this behaviour is assumed to reach an adequate level. Although even slight fog should represent an influence upon the variations in such links, the extrapolated advancement in predicting the occurrence of such detrimental effects should permit the employment of diversity methods within an operational net, in other words, a kind of net diversity system. Ultimately, the reliability of links in that frequency range should thus be adequate for ordinary applications.

As the second category, research progress is to be considered as far as the field of electromagnetic wave propagation is concerned. Obviously, the appropriate advancement is also connected to the progress to be anticipated in the more technological area. On the other hand, this kind of progress will concern, to a larger extent, the adaptation of propagation media to the

needs of society. To use a more precise definition, the field of artificial modification of propagation media should gain a predominant emphasis, while no harmful changes occur with the atmospheric environment. Whereas the present status of this field of research is very closely connected to the artificial influence upon the atmospheric environment, the trend of future development may be directed more precisely towards a modification of environmental media for the main purpose of stabilizing electromagnetic wave propagation on links of various kinds. With a somewhat more direct reference to AGARD activities, the Panel on Electromagnetic Wave Propagation sponsored a specialists' meeting in April 1976 as the first international scientific meeting which specifically covered anthropogeneous atmospheric changes for the purpose of intentionally modifying propagation media. It is to be assumed that, in about 20 to 30 years, propagation media may be modified artificially such that the appropriate operational links will be far more reliable than their present counterparts on the same frequencies.

Summarizing these few comments on a possible long-term trend as far as electromagnetic wave propagation is concerned, future tasks will have to be directed towards more and more advances in research and development and will have to be adapted to changing requirements. For the AGARD Panel on Electromagnetic Wave Propagation, this objective may be identified as a continuation of active contributions to basic research and to application-oriented interpretation of scientific results for the benefit of the NATO-community.



HELMUT LANGFELDER

On the sixth of April this year, in Marignane, Helmut Langfelder lost his life when, during a visit to the French aircraft industry, the helicopter in which he was travelling crashed. With this tragic event the NATO aerospace community lost an outstanding engineer and leader.

Helmut Langfelder, who was born in Vienna, was only forty-nine. He was a man of great charm and energy and had risen to become Chairman of the Messerschmitt-Bölkow-Blohm (MBB) Board of Directors, a position he assumed just three months before his death.

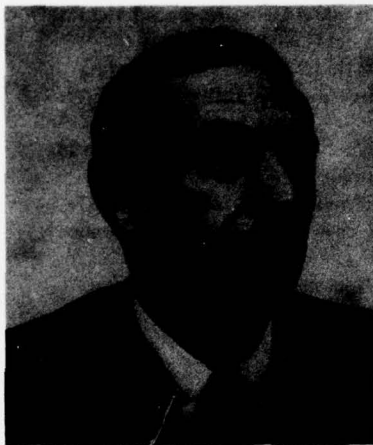
His career started shortly after the war when he read mathematics and physics in Sydney, subsequently going on to continue his studies at the London School of Economics. Thereafter, in 1952, he joined Messerschmitt AG as a design and development engineer. In 1958 he became responsible for the Aerodynamics and New Projects Department before taking over, a year later, the post of Chief Departmental Head, Aerodynamics and Flight Mechanics, in Entwicklungsring Süd (EWR), Munich.

Probably one of the most important phases of his work started in 1970 when he moved to MBB, München, as Chief of the Multi-Role Combat Aircraft programme. As anyone associated with the MRCA will know, this multi-national venture has been one of extraordinary technical and political complexity. Helmut Langfelder knew all about the significance of international collaboration in aviation and the adeptness with which he practised it came to be recognized as a hall-mark to his work.

AGARD is grateful to have had him as a member of its National Delegates Board, albeit for only a few brief months, and, along with his colleagues in MBB and the Ministry of Defence of the Federal Republic of Germany, AGARD greatly mourns his passing.

Von Kármán Medals 1978

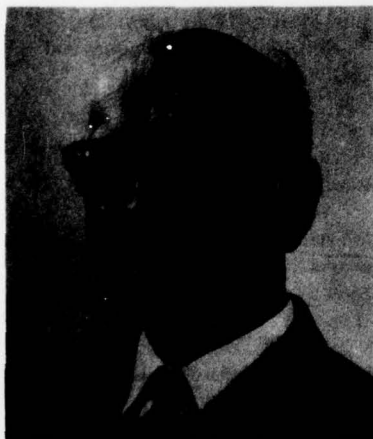
The 1978 Von Kármán Medals have been awarded to Dr Alexander H. Flax (United States) and Professor van Oosterom (The Netherlands). Presentations will be made at the Fall 1978 meeting of the AGARD National Delegates Board, and the citations which accompany the medals read as follows:



DR ALEXANDER H. FLAX is recognized as an international authority in aerospace science and technology. He has made major contributions in the fields of fluid mechanics, aeropropulsion, and aerospace vehicle design.

Dr Flax has served as a US National Delegate to AGARD since 1969, and as Chairman of the National Delegates Board from 1973 through 1976. He has been a member of the Executive and Advisory Committees since 1969, and was a member of the Steering Committee from 1971 through 1976.

His broad experience in aerospace research, both from the laboratory point of view and from that of directing large research efforts on both national and international scales, has formed the basis of his valuable contributions to AGARD.



PROFESSOR TEUNIS VAN OOSTEROM made valuable contributions to many AGARD meetings for over twenty years. From 1960 until the end of 1977 he gave dedicated service to AGARD, as a member of the Flight Mechanics Panel, including membership of various working groups and as Chairman of the Flight Test Instrumentation Committee. Showing great ability to bring together people from many nations for a common effort, he was the moving spirit in the compilation of the important Flight Test Instrumentation Series of publications. His personal example and his enthusiasm has inspired authors from many quarters to provide AGARD with the best of their combined knowledge, for the benefit of the NATO community.

CALENDAR OF PLANNED MEETINGS
1979

<i>Tentative Dates</i>	<i>Location</i>	<i>Panel</i>	<i>Type of Meeting/Subject</i>
22-26 January	BELGIUM (Brussels)	Aerospace Medical	Specialists' Meetings on - Maintenance of Air Operations while under Attack with Chemical Agents (Classified) - Recent Advances in Aeronautical and Space Medicine
5-6 March	TURKEY (Ankara)	Fluid Dynamics	Lecture Series No.98 Missile Aerodynamics
8-9 March	ITALY (Rome)	Fluid Dynamics	Lecture Series No.98 Missile Aerodynamics
12-16 March	BELGIUM (VKI, Brussels)	Fluid Dynamics	Lecture Series No.98 Missile Aerodynamics
21-23 March	FRANCE (Paris)	Headquarters	46th National Delegates Board Meeting 26th Panel Chairmen Meeting 9th National Coordinators Meeting 26th Steering Committee Meeting
1-6 April	UNITED STATES (Williamsburg, Va)	Structures & Materials	48th Panel Meeting/Specialists' Meeting - Damping Effects in Aerospace Structures - Low-cost Aircraft Flutter Clearance
2-6 April	NORWAY (Kolsås)	Propulsion & Energetics	53rd Panel Meeting/Symposium on Solid Rocket Motor Technology (Classified)
2-3 April	NORWAY (Oslo)	Structures & Materials	Lecture Series No.102 Bonded Joints and Preparation for Bonding
5-6 April	NETHERLANDS (The Hague)	Structures & Materials	Lecture Series No.102 Bonded Joints and Preparation for Bonding
9-13 April	TURKEY (Ankara)	Avionics	37th Panel Meeting/Symposium on Avionics Reliability, its Techniques and Related Disciplines
23-24 April	UNITED KINGDOM (London)	Propulsion & Energetics	Lecture Series No.103 Non-Destructive Inspection Methods for Propulsion Systems and Components
26-27 April	ITALY (Milan)	Propulsion & Energetics	Lecture Series No.103 Non-Destructive Inspection Methods for Propulsion Systems and Components
7-8 May	GERMANY (Bonn)	Avionics	Lecture Series No.100 Methodology for Control of Life Cycle Costs for Avionics Systems
10-11 May	GREECE (Athens)	Avionics	Lecture Series No.100 Methodology for Control of Life Cycle Costs for Avionics Systems
7-11 May	CANADA (Ottawa)	Guidance & Control	28th Panel Meeting/Symposium on Advances in Guidance and Control Systems using Digital Techniques (Classified)

<i>Tentative Dates</i>	<i>Location</i>	<i>Panel</i>	<i>Type of Meeting/Subject</i>
14-17 May	ITALY (Naples)	Fluid Dynamics	44th Panel Meeting/Symposium on Aerodynamic Characteristics of Controls
21-23 May	UNITED STATES (Washington)	Military Committee Studies	P2000 Review Board
24-25 May	UNITED STATES (Washington)	Aerospace Applications Studies Committee	Final Studies Review
21-25 May	UNITED KINGDOM (London)	Flight Mechanics	54th Panel Meeting/Symposium on Missile System Flight Mechanics (Classified)
28 May-1 June	PORTUGAL (Lisbon)	Electromagnetic Wave Propagation	Symposium on Special Topics in H.F. Propagation
4-5 June	ITALY (Rome)	Guidance and Control	Lecture Series No.101 Guidance and Control for Tactical Guided Weapons with Emphasis on Simulation and Testing
7-8 June	TURKEY (Ankara)	Guidance and Control	Lecture Series No.101 Guidance and Control for Tactical Guided Weapons with Emphasis on Simulation and Testing
11-12 June	UNITED STATES (Eglin AFB, Fa)	Guidance and Control	Lecture Series No.101 Guidance and Control for Tactical Guided Weapons with Emphasis on Simulation and Testing
4-5 June	UNITED KINGDOM (London)	Electromagnetic Wave Propagation	Lecture Series No.99 Aerospace Propagation Media Modelling and Prediction Schemes for Modern Communications Navigation and Surveillance Systems
14-15 June	UNITED STATES (Boulder, Co)	Electromagnetic Wave Propagation	Lecture Series No.99 Aerospace Propagation Media Modelling and Prediction Schemes for Modern Communications Navigation and Surveillance Systems
3-6 September	GERMANY (Munich)	Flight Mechanics	55th Panel Meeting/Symposium on the Use of Computers as a Design Tool
10-14 September	NORWAY (Spåtind)	Electromagnetic Wave Propagation	26th Panel Meeting/Specialists' Meeting on Terrain Profiles and Contours in E.M. Propagation
19-21 September	ITALY (Florence)	Headquarters	15th Annual Meeting 47th National Delegates Board Meeting 27th Panel Chairmen Meeting
24-28 September	NETHERLANDS (The Hague)	Fluid Dynamics	45th Panel Meeting/Symposium on Turbulent Boundary-Layers - Experiments, Theory and Modelling
24-28 September	GERMANY (Cologne)	Propulsion & Energetics	54th Panel Meeting/Specialists' Meeting on a) Advanced Control Systems for Aircraft Power Plant (Classified) b) Combustor Modelling

<i>Tentative Dates</i>	<i>Location</i>	<i>Panel</i>	<i>Type of Meeting/Subject</i>
30 September– 5 October	GERMANY (Cologne)	Structures & Materials	49th Panel Meeting/Specialists' Meeting on Ceramics for Small Turbines (with participation of PEP)
4–5 October	FRANCE (Paris)	Aerospace Medical	Lecture Series No.105 Intensive Air Operations: Problems of Sleep, Wakefulness and Circadian Rhythms
8–9 October	CANADA (To be advised)	Aerospace Medical	Lecture Series No.105 Intensive Air Operations: Problems of Sleep, Wakefulness and Circadian Rhythms
8–12 October	DENMARK (Copenhagen)	Guidance & Control	29th Panel Meeting/Symposium on Tactical Air Traffic Management Systems and Technology (Classified)
15–19 October	FRANCE (Paris)	Avionics	38th Panel Meeting/Symposium on Modelling and Simulation of Avionics Systems and Command, Control and Communications Systems
16–18 October	GREECE (Athens)	Technical Information	32nd Panel Meeting/Specialists' Meeting on Review of Developments in R & D Information Transfer
22–26 October	PORTUGAL (Lisbon).	Aerospace Medical	36th Panel Meeting/Specialists' Meeting on – Aircrew Systems and Human Factors in Future High Performance Aircraft (with possible participation of FMP, GCP and TIP) – Low Altitude/High-Speed Flight – Aircrew Factors (with GCP and FMP)
29–30 October	NETHERLANDS (Delft)	Flight Mechanics	Lecture Series No.104 Parameter Identification
1–2 November	UNITED KINGDOM (London)	Flight Mechanics	Lecture Series No.104 Parameter Identification
13–14 November	GERMANY (Munich)	Military Committee Studies	P2000 Review Board Final Report Review
15–16 November	GERMANY (Munich)	Aerospace Applications Studies Committee	16th Meeting

Note: Meetings of the Military Committee Studies P2000 Working Groups are not included in this Calendar

TRADUCTION DES TITRES DES REUNIONS

Titles of Meetings

Titres des Réunions

Aerospace Medical Panel

- | | |
|--|--|
| <ul style="list-style-type: none"> – Maintenance of Air Operations while under Attack with Chemical Agents – Recent Advances in Aeronautical and Space Medicine – Aircrew Systems and Human Factors in Future High-Performance Aircraft – Low Altitude/High Speed Flight – Aircrew Factors | <ul style="list-style-type: none"> – Maintien des Opérations Aériennes au cours d'Attaques par Agents Chimiques – Progrès Récents en Médecine Aéronautique et Spatiale – Systèmes à l'usage des Equipages, et Facteurs Humains, dans les Futurs Avions à Grandes Performances – Facteurs liés aux Equipages dans les Vols à Basse Altitude et Grande Vitesse |
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Avionics Panel

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| <ul style="list-style-type: none"> – Avionics Reliability, its Techniques and Related Disciplines – Modelling and Simulation of Avionics and Command, Control, and Communications Systems | <ul style="list-style-type: none"> – Fiabilité de l'Electronique Aérospatiale – Techniques et Disciplines Connexes – Modélisation et Simulation des Systèmes Electroniques Aérospatiaux et des Systèmes de Commande, de Contrôle et de Communications |
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Electromagnetic Wave Propagation Panel

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| <ul style="list-style-type: none"> – Special Topics in HF Propagation – Terrain Profiles and Contours in EM Propagation | <ul style="list-style-type: none"> – Problèmes Spécifiques de Propagation des Ondes HF – Profils et Contours de Terrain dans la Propagation des Ondes EM |
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Flight Mechanics Panel

- | | |
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| <ul style="list-style-type: none"> – Missile System Flight Mechanics – The Use of Computers as a Design Tool | <ul style="list-style-type: none"> – Mécanique du Vol des Systèmes de Missiles – L'Ordinateur en tant qu'Instrument de Conception |
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Fluid Dynamics Panel

- | | |
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| <ul style="list-style-type: none"> – Aerodynamic Characteristics of Controls – Turbulent Boundary-Layers – Experiments, Theory and Modelling | <ul style="list-style-type: none"> – Caractéristiques Aérodynamiques des Commandes – Couches Limites Turbulentes – Expériences, Théorie et Modélisation |
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Guidance and Control Panel

- | | |
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| <ul style="list-style-type: none"> – Advances in Guidance and Control Systems using Digital Techniques – Tactical Air Traffic Management Systems and Technology | <ul style="list-style-type: none"> – Progrès en matière de Systèmes de Guidage et Contrôle Utilisant des Techniques Numériques – Systèmes et Technologie de Gestion du Trafic Aérien Tactique |
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Propulsion and Energetics Panel

- | | |
|---|--|
| <ul style="list-style-type: none"> – Solid Rocket Motor Technology – Advanced Control Systems for Aircraft Powerplants – Combustor Modelling | <ul style="list-style-type: none"> – Technologie des Moteurs Fusées à Propergol Solide – Systèmes Avancés de Commande pour Groupes Propulseurs d'Avions – Modélisation des Chambres de Combustion |
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Structures and Materials Panel

- | | |
|---|--|
| – Damping Effects in Aerospace Structures | – Les Effets de l'Amortissement dans les Structures Aérospatiales |
| – Low-Cost Aircraft Flutter Clearance | – Certification, du point de vue Flottement, des Avions de Faible Coût |
| – Ceramics for Small Turbines | – Céramiques pour Turbomoteurs de Petites Dimensions. |

Technical Information Panel

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| – Review of Developments in R&D Information Transfer | – Bilan des Réalisations en matière de Transfert d'Informations sur la Recherche et le Développement |
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Lecture Series

- | | |
|---|---|
| – Missile Aerodynamics | – L'Aérodynamique des Missiles |
| – Aerospace Propagation Media Modelling and Prediction Schemes for Modern Communications, Navigation and Surveillance Systems | – Schémas de Modélisation et de Prédiction des Milieux de Propagation Aérospatiaux pour Systèmes Modernes de Communications, de Navigation et de Surveillance |
| – Methodology for Control of Life-Cycle Costs for Avionics Systems | – Méthodologie du Contrôle des Coûts de Cycle de Vie des Systèmes Electroniques Aérospatiaux |
| – Guidance and Control for Tactical Guided Weapons with Emphasis on Simulation and Testing | – Guidage et Contrôle des Armes Tactiques Guidées – en particulier, Simulation et Essais |
| – Bonded Joints and Preparation for Bonding | – Joints Collés et Préparation au Collage |
| – Non-Destructive Inspection Methods for Propulsion Systems and Components | – Méthodes d'Examen non Destructif des Systèmes Propulsifs et de leurs Composants |
| – Parameter Identification | – Identification de Paramètres |
| – Intensive Air Operations – Problems of Sleep, Wakefulness and Circadian Rhythms | – Opérations Aériennes Intensives: Problèmes de Sommeil, de Vigilance et de Rythme Circadien |

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| – AASC Meetings and Working Groups | – Réunions de l'AASC et Groupes de Travail |
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Project 2000

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| – Review Board Meetings | – Réunions du Comité Directeur |
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Headquarters

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| – AGARD Annual Meeting | – Réunion Annuelle de l'AGARD |
| – National Delegates Board Meetings | – Réunions du Conseil des Délégués Nationaux |
| – Steering Committee Meeting | – Réunion du Comité d'Orientation |
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